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UNITED STATES
DEPARTMENT OF THE INTERIOR
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INFORMATION CIRCULAR

HOME INSULATION WITH MINERAL PRODUCTS -- CONSERVATION OF FUEL FOR WAR

BY

OLIVER BOWLES

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HOME INSULATION WITH MINERAL PRODUCTS – CONSERVATION OF FUEL FOR WAR 1/ 2/

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INTRODUCTION

The exingencies of a world war have brought home to the American public, especially the people of the Eastern States, the urgent need for conserving fuel. Transportation problems in the East have created an unprecedented situation wherein fuel-oil supplies are greatly restricted, and the consequent increase in demand for coal further complicates the problem of transporting and storing that commodity. People should awaken to the need for utilizing every possible means of conserving fuel, even to the extent of reducing the temperature in their homes.

1/ The Bureau of Mines will welcome reprinting this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7220."

2/ Some of the data given in this paper were taken from Bureau of Mines Inf. Circ. 7166, Home Insulation, by Paul M. Tyler, a report now out of print.

3/ Chief, Nonmetal Economics Division, Bureau of Mines.

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There never was a time in the history of our Nation when it was more necessary to practice economy in household heating. Such economy is not merely the instrumentality whereby physical comfort and wellbeing may be maintained; it has attained the dignity of a patriotic duty, because every ton of coal or gallon of oil saved conserves these fuels for military needs and releases facilities for transporting munitions, the raw materials required for their manufacture, or a multitude of other products involved in the war program. Aside from this unusual emergency in the East, conservation of fuel resources is desirable at all times and in all localities.

Readers are referred to a recent Bureau of Mines information circular by J. F. Barkley entitled "How to Save Fuel at Home", which whould be consulted with regard to economical use of solid fuels.

HOW FUEL MAY BE SAVED

Fuel saving naturally begins at the source, and to produce heat efficiently for a given dwelling requires selecting the proper fuel and burning it in a furnace designed to release as much as possible of the heating value of the fuel. This process is complicated and involves not only proper burning of fuel but also capture of the heat in a suitable transmitting medium - steam, water, or air. Efficient production of heat, therefore, is still a fruitful field for research in fuel saving. Studies of the efficient use of heat cover another vast technologic field and have proved invaluable to the commercial success of many process industries. True economy in heating the home, however, has never commanded the attention it deserves.

In the field of new-home construction the use of high-grade, substantial building materials, careful planning, and skilled workmanship are important in fuel conservation. Weatherstripping and storm windows and doors are widely recognized as contributory means of conserving heat.

One of the chief elements in fuel saving is insulation. To the ordinary home owner, insulation is simply a more or less effective barrier to retain heat in winter and keep it out in summer. Common insulating materials are mineral wool (also called rock wool, glass wool, and slag wool), vegetable and wood fiber in various forms, asbestos, insulating boards made of vegetable or mineral products, vermiculite, diatomite, pumice and other porous rocks or earths, magnesia, aluminum foil, sawdust, animal hair, and cork; in this paper those of mineral origin only will be considered. Insulation is achieved by using such materials to fill the open spaces in walls and ceilings.

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ADVANTAGES OF INSULATION

Aside from conservation of fuel, home insulation has many advantages. If in the process of saving fuel home temperatures may be maintained at comfortable levels without subjecting the occupants to chills and drafts, public health will be promoted and additional man-hours of productive effort will be gained.

Protection against fire is another advantagious function of insulation. Incombustible heat-insulating barriers in roofs and walls make even frame buildings slow-burning. Years ago, when insulation cost more, salesmen stressed its fire-resistance more than its comfort-giving and fuel-saving properties. The George Washington shrine at Mount Vernon was insulated upon the recommendation of the National Bureau of Standards, because mineral wool placed between rafters and in the walls around dormer windows would inhibit the spread of fire. Recent tests at the National Bureau of Standards showed that a wood-lath partition filled with mineral wool will stop the passage of fire for 1 hour, at the end of which time the studs were still able to carry their load.

Still another advantage, seldom stressed but well-recognized by mortgage lenders, is the fact that insulation in side walls and ceilings reduces the number of times the interior of a house must be redecorated during the lifetime of a loan. With wallpaper and paint in better condition, the house is not only a better place in which to live but a better mortgage risk; it is easier to rent or sell; and since redecorating costs as well as fuel costs come out of the borrower's income, the chances of delinquency in meeting payments are reduced. Dust patterns and alternate light and dark strips along laths and beams are less likely to occur in well-insulated homes. First, there is less movement of air to carry particles of dust along unevenly heated surfaces, and second, there is less condensed moisture on the surfaces to catch the dust. Moreover, as cold walls are likely to be damp, condensed moisture alone may cause discoloration.

HOW INSULATION WORKS

James Watt insulated his primitive steam engine and its boiler with strips of wood, a proof that even then industry had begun to appreciate the economy of conserving heat energy. Mineral wool was used as steam-plant insulation as early as 1840. Whenever heat or refrigeration is used in industry, insulation guards against waste. In many modern industrial processes based upon reactions that take place only within a narrow temperature range, insulation not only is economical but necessary, because close control of temperature is almost impossible without insulation.

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Heat is transferred in three ways - by conduction, convection, and radiation. With respect to insulation, conduction is the most important; and as heat is dissipated first through conduction, a well-insulated surface automatically reduces convection and radiation losses to a minimum.

Conduction, or the flow of heat through a solid, may be noted along a silver spoon when it is used to stir hot coffee. Convection is a more complicated phenomenon but is often manifested by "drafts" or movement of air as well as by leakage of air around window and door frames. Radiation is the process that carries the sun's heat to the earth and is familiar to anyone who has sat by an open fire; it also takes place between the objects in a room and the outside walls.

Although air is a poor conductor of heat, open air spaces in the hollow walls of a building do not afford much insulation, largely because of radiation from one wall to the other. Some heat also is lost by convection (the term "dead-air space" is a misnomer), but not so much as many suppose.

In any enclosed structure where human beings should be comfortable in winter - home, factory, office building, or school - the principal function of the heating system is to prevent body heat from being dissipated too rapidly for health. If walls, ceilings, or floors become too cold, discomfort results; and even with the finest heating plant in the world, surfaces exposed to the weather are likely to become too cold unless they are heavily insulated. The same insulation helps to keep surfaces cool in summer.

Heat is measured in British thermal units; 1 B.t.u. of heat is required to raise 1 pound of water 1° F. under specified conditions (from 39° to 40°F. at sea level). Heat losses are measured in B.t.u. per square foot per hour per °F. temperature difference - in other words, in terms of the quantity of heat that will pass through a section of given material 1 square foot in area and 1 inch thick in an hour, divided by the difference between the outside and inside temperatures. This quantity is sometimes called the k-factor; and as it is the measure of heat loss, the smaller this constant is for a given material the better the insulating properties of the material. Thermal conductivity or k-factor of most light, fibrous materials sold primarily as insulators ranges from 0.25 to 0.35 B.t.u. per hour.

The following table shows the thermal conductivity of a variety of materials, many of which are used in home construction.

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Thermal conductivity of various materials[1/]

Material tested	Density, lb. per cu. ft.	Conductivity
Air space between walls (3 1/2-in.)..	0.081	0.83 to 1.10
Cotton, compressed	6.3	.21 to .29
Pure wool	6.24	.26 to .32
Silk.....	6.24	.28 to .34
Hair felt	13.0	.26
Flax fiber	13.0	.31 to .33
Cork, ground	8.1	.27 to .31
Sugarcane fibers	13.5	.34
Pine wood	34.3	.8 to 1.0
Wood-pulp board, plaster base	16.2	.3 to .4
Mineral wool	2 to 7	.27 to .30
Magnesia (85 percent magnesia, 15 percent asbestos)	19.3	.47 to .51
Expanded vermiculite.....	6 to 7	.48
Diatomite powder	10.6	.3 to .5
Diatomite blocks	28.1	.58
Pumice gravel	18.8	.64
Tile (clay and plaster)	12.7	.60
Glass, plate	15.5	3.6 to 7.3
Bricks, dry.....	125.0	3.0 to 3.0
Brickwork (mortar bond)	132.0	4.0 to 5.0
Gypsum plaster	46.2	2.0 to 5.0
Concrete, 1-2-4	150.0	5.0 to 9.0
Slate shingles	162 to 205	10.0 to 10.4
Building stone	165.0	12.5
Steel, 1 percent carbon	489.0	314.0 to 328.0
Copper pure	558.0	2,580.0 to 2,670.0
Silver, (greatest conductivity).....	655.0	2,860.0 to 2,920.0

1/ Authorities: National Bureau of Standards, Federal Housing Administration, and university and research laboratories.

2/ Conductivity = British thermal units transmitted per hour per square foot of material 1 inch thick, per °F. difference in temperature of the two faces.

Heating requirements are measured by engineers in degree-days. The heating season in the United States is, roughly, October 1 to May 1, but it varies greatly in different parts of the country. Degree-days, however, are published in heating handbooks and in United States Weather Bureau reports for nearly every city in the United States and Canada. They are based upon mean-temperature data. One degree below 65°F. for a 24-hour period equals 1 degree-day. The assumption is that no artificial heat is required when the mean daily outside temperature is 65°F.

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SAVING ACCOMPLISHED BY INSULATION

Enormous quantities of fuel are used for heating buildings. The following data for the United States for 1941 have been compiled by the Coal Economics Division of the Bureau of Mines from various sources. The total anthracite used for space-heating purposes was approximately 44,000,000 tons. The quantity of bituminous and other classes of coal so used is somewhat uncertain but was about 66,000,000 tons. Coke for space heating amounted to about 9,000,000 tons and fuel oil so used aggregated 209,000,000 barrels. The quantity of gas used for space heating is uncertain but approximates 250 billion cubic feet. The total value of these products at the point of origin was approximately $800,000,000. The price paid by the consumer, including transportation charges and retailers' expenses and profits, was roughly $2,000,000,000. This prodigious figure for keeping people warm indicates the enormous potential field for saving when economies are introduced.

The National Bureau of Standards has demonstrated (T.I.B.M. 15, May 18, 1936) that frame construction, with wood shingles over building paper, 3/4-inch wood sheathing outside, and 3/4-inch plaster and metal lath (or 1/2-inch plasterboard or wallboard alone) inside, had an insulating value[4/] of 4.6 when the 3-5/8-inch air space was unfilled. When this space was filled with mineral wool the value rose to 16.0. Corresponding figures for a 4-inch brick-veneer wall over the same paper and sheathing and the same interior wall finish were 3.7 when the air space was unfilled and 15.1 when it was filled (T.I.B.M. 14).

Another interesting Bureau of Standards tabulation (T.I.B.M. 3, March 4, 1933) estimates fuel savings up to 40 percent due to the application of simple heat-loss preventives to walls and roof of an unprotected house, and with suitable weatherstripping and storm sash applied to doors and windows the total savings were boosted to 60 percent.

To judge the saving that may be achieved with insulation, reference may be made to a Canadian report[5/] embodying the results of a study made on the distribution of heat losses in homes. The study was made on 200 average homes of wood-frame construction, uninsulated, and without weatherstripping or storm windows or doors. It was found that of the heat lost, 16.2 percent was lost through the roof, 27.0 percent through the walls, 25.8 percent through the glass, 24.6 percent by air infiltration, 4.3 percent through the door, and 2.1 percent through other sources, including the floor. When 2 inches of insulating material was applied to the walls of these houses, the

4/ The unit in these tests was the number of hours required for passage of 1 B.t.u. of heat through 1 square foot of wall area per 1°F. temperature difference between air on one side to air on other side.

5/ Babbitt, J. D., and Hyland, John J., House Insulation in Its Relation to Canada's War Effort: Document N.R.C. 1055, National Research Council of Canada and National Housing Administration, Department of Finance, Ottawa, Canada, 1942.

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heat loss was reduced 17.4 percent; and the addition of 2 inches of insulation to the second-floor ceiling brought about a further reduction of 13.3 percent. Thus, complete insulation saved 30.7 percent of the heat loss.

There is, of course, definite relationship between heat conservation and fuel saving. The quantity of fuel that may be saved by insulation has been determined by many investigators, and the results vary considerably, but in every instance the figures obtained are remarkably large. One of the most complete and dependable studies is that conducted by the Engineering Experiment Station, University of Illinois, on a three-story residence of standard frame construction in Urbana, Ill. Both ceiling and walls of the house were insulated with mineral-wool batts wherever they could be applied conveniently, and in other places nodulated mineral wool having a density of about 5 pounds per cubic foot was blown into place. The results of the tests, which have been described in detail[6/], indicate that insulation produced an average saving of approximately 30 percent in consumption of fuel. This figure agrees closely with the 30.7 percent of heat loss saved by insulation given in the Canadian report to which reference has been made.

It is difficult to estimate the actual saving in tons of coal, gallons of oil, and cubic feet of gas that can be accomplished by insulation, because a large percentage of the new homes built in the United States during recent years were insulated when built. Furthermore, during the past 12 or 15 years multitudes of existing homes have been insulated by blowing the insulating medium into the walls and between floor joists and rafters. Undoubtedly millions of homes still lack insulation, and if 30 percent of the fuel used in such homes can be saved by insulation, the total saving can be measured in terms of millions of tons of coal and vast quantities of other fuels.

HOW TO INSULATE

Choice of insulating materials depends largely on relative availability and cost. Generally, mineral products are preferable because of their resistance to fire, electrical short circuits, moisture, termites, vermin, and decay. In new-home construction, if the home owner employs a competent and responsible building contractor, he may expect to have the insulating done properly. The application of insulation to existing homes is a special art. It is important that all open spaces in ceilings and walls be completely filled with the insulating medium. If barriers prevent movement of the fill material, a new opening should be made beyond the barrier. Obviously, leaky roofs and walls should be repaired, so that moisture will not accumulate in the fill. Problems involving the relative merits of various insulating materials and their proper application are not within the province of the

6/ Kratz, A. P., and Konzo, S., Effect of Insulation on Plant Performance in the Research Residence: Heating, Piping, and Air-Conditioning, May 1941, pp. 318-324.

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Bureau of Mines. The National Bureau of Standards has conducted many studies on insulating problems, and various insulating firms have developed knowledge and skill in application.

Attention may be directed to a new motion-picture film in sound produced by the Bureau of Mines, United States Department of the Interior, in cooperation with a large industrial concern. Under the title "Heat and Its Control. The Story of Rock-Wool Home Insulation" it tells how insulation of homes may conserve the Nation's fuel supply and thereby contribute to the success of the military program.

INSULATION PRODUCTS OF MINERAL ORIGIN

Mineral Wool

Mineral wool consists of fine, interlaced mineral fibers having the appearance of loose wool or cotton. It is a fibrous, glasslike material composed principally of silicates of calcium and aluminum. Mineral wool is a generic term covering a number of similar products differentiated chiefly by the raw materials from which they are made. "Rock wool" is made from natural rock (a calcareous shale) or from combinations of various natural minerals or rocks, such as limestone and shale. "Slag wool" is made from iron, copper, or lead blast-furnace slag alone or mixed with fluxing materials. "Glass wool" is made from silica sand, soda ash, and limestone with or without scrap glass or other materials.

The first step in the process of making rock wool is to melt the raw materials, consisting of a properly proportioned mixture of alumina, silica, and lime or magnesia, in a cupola furnace. The molten material is then drawn from the bottom of the cupola in a small stream, the flow and temperature of which are regulated carefully. The slag, as it falls, is broken up by a steam jet (at 80 to 100 pounds pressure) into minute droplets, which, while still molten, are propelled rapidly through the air. During their cometwise course fine threads of glasslike material form as tails and fall in a fluffy mass on the floor of the wool room. When freed from glassy shot grains, it is ready for use or for manufacture into mineral-wool products. Molten furnace slag or glass is made into wool by similar processes. If molten slag can be blown into wool just as it comes from the metallurgical furnace the cost of melting is saved.

Mineral wool is marketed in various forms. Loose wool is the raw product as blown and without subsequent treatment. This is the material from which all mineral-wool products are made. Nodulated or granulated wool has been freed from shot and rolled into small pellets, so that it can

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be blown into place through an air hose; it is used chiefly for insulating houses already built. Increasing quantities of wool are fabricated into soft, flexible quilts confined between layers of vapor-proofed paper. "Batts" are rectangular shapes made from loose wool mixed with suitable binders, compressed, and cut to the thickness and size demanded by consumers. Batts may have one or two paper covers or none at all. They are used for insulating new houses, being inserted in walls, floors, or roofs between studs, joists, or rafters. Roll wool is wool matted like cotton batting and rolled with paper. Blankets, used largely for insulation of industrial furnaces, are made of loose wool treated with binders and are of various rectangular shapes and thicknesses, sewed between wire, metal lath, or other confining mediums. Loose wool with suitable binders also is compressed into blocks for use in refrigerator, stove, and furnace insulation and into various shapes for pipe and boiler coverings. Loose wool mixed with bentonite or plastic fire clay and asbestos fiber is sold as an insulating cement for filling joints between insulating blocks, as plastic insulation for irregulary shaped objects, and for general heat-conservation use.

Vermiculite

Vermiculite is another important mineral insulating material. It received its name from its peculiar property of expanding and unfolding into wormlike forms when heated. The name is applied to a group of micaceous minerals that generally are alteration products of biotite, phlogopite, and other varieties of mica. The most pronounced characteristic of vermiculite is its extraordinary expansion in heating; the volume may increase up to 16 times the original. The porous nature of the expanded mineral makes it an ideal heat insulator. It is mined chiefly in Montana, but also in Wyoming and North Carolina, and is processed in plants situated at various strategic points in the United States. It takes the form of feather-light, resilient pellets, which, when screened or sized to remove particles that are too large or too small, are used as loose fill. Insulating cements made from expanded vermiculite screenings and bentonite or other binder are manufactured by several firms, and at least one manufacturer has produced a compressed vermiculite wallboard. Plaster and concrete, in which vermiculite takes the place of sand or other aggregate, are being used in rapidly increasing quantities; in addition to their heat-insulating value, they have acoustic properties and are light in weight. Vermiculite precast-concrete slabs for roof, floor, or wall construction weigh as little as 25 pounds per cubic foot and are easy to install. If necessary, they can be sawed, cut with a knife, drilled, or nailed in much the same way as wood lumber.

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Other Mineral Insulators

Diatomite, pumice, and other porous rocks or earths have been used for wall insulation, and diatomite, asbestos, and magnesia (chiefly a mixture of 85 percent technical carbonate and 15 percent asbestos fiber) are used extensively for boiler and pipe coverings.

Aluminum foil is used to increase the value of air spaces by reducing transfer of heat by radiation. Clean metallic surfaces usually are good reflectors and poor emitters of radiant heat, and as much of the transfer of heat across open spaces in buildings takes place by radiation, the use of aluminum on one or both sides of the space may reduce heat losses substantially. Aluminum foil also is applied in crumpled form to be self spacing.

Stiff, fibrous insulating boards having considerable structural strength usually are not as good insulators as lighter, looser materials. Heavy wallboards containing some form of gypsum, although excellent building materials, are relatively poor insulators.7/ Ordinarily, the lower the density, the better the insulating value.

PRODUCTION STATISTICS

The production of mineral wool (home insulation only) during recent years, as reported by the National Mineral Wool Association, is indicated in the following table:

Mineral wool (home insulation only) sold in the United States, 1937-41

Year	Short tons	Value
1937.....	129,335	$8,396,823
1938	87,593	6,314,408
1939	100,771	7,323,476
1940	157,460	11,346,650
1941.....	215,422	14,001,203

Production of vermiculite since 1924, as reported to the Bureau of Mines by producers, is given in the following table:

7/ National Bureau of Standards, Technical Information on Building Materials: No. 16, May 22, 1936.

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Vermiculite sold or used by producers in the United States, 1924-41

Year	Short tons	Value	Year	Short tons	Value
1924.....	2	$38	1933.....	2,247	$21,993
1925.....	102	2,318	1934.....	4,746	56,965
1926.....	150	3,750	1935.....	7,068	88,445
1927.....	51	1,318	1936.....	16,933	185,787
1928.....	1,006	38,118	1937.....	23,556	260,634
1929.....	932	24,483	1938.....	20,700	192,000
1930.....	831	13,682	1939.....	21,174	174,587
1931.....	1,256	24,758	1940.....	22,299	137,698
1932.....	1,643	16,950	1941.....	23,438	125,444

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